Ministry for Primary Industries
Manatū Ahu Matua

Treatments for Brown Marmorated Stink Bug

MPI Technical Analysis

Prepared by Facilities and Pathway Group

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1 Purpose

The purpose of this document is to review available information and propose treatments against Brown Marmorated Stinkbug (BMSB), *Halyomorpha halys,* associated with cargo (particularly vehicles) imported into New Zealand.

2 Background

The Brown Marmorated Stinkbug is a temperate subtropical species of stink bug native to Asia. It is an indiscriminate generalist plant feeding insect that feeds on the leaves and fruits of a very wide range of trees (including horticultural, domestic), field crops, as well as production forestry tree species.

The areas where it has established outside of its natural region have experienced significant economic impacts to a wide variety of crops. The bug also causes significant public nuisance due to its tendency to aggregate indoors during the winter, with some infested residential areas reported experiencing plague proportions at population peaks. Since being introduced into North America in 1996, BMSB has spread across the US and Canada, and more recently (2007) into Europe and Chile (2017).

BMSB is a highly cryptic pest at low levels. It is a hitchhiking pest that has no biological association with any pathway. This means it is hard to predict specific risk pathways. The Brown Marmorated Stinkbug propensity to aggregate as infertile adults to overwinter indoors and in manufactured goods increases the chances of it hitchhiking on imported goods as a result. It is not the goods themselves that pose the risk, it is where they come from, storage conditions, the time of year, and the surrounding environment that contribute to the likelihood of contamination by BMSB.

The MPI risk analysis (MPI 2012) identified the BMSB risk period to be from mid-September to the end of April. This time frame aligns with the overwintering habits of BMSB in the Northern Hemisphere countries where it has become increasingly invasive. This high risk period is referred to as the “risk season”.

Since 2014, the interception rates of Brown Marmorated Stink Bug during the risk season at the border has increased from sources outside of its natural range. As a result MPI has been increasing its border interventions and risk management measures on the pathways where the presence of Brown Marmorated Stink Bug has increased.

A summary of the regulatory measures MPI has implemented for Brown Marmorated Stink Bug:

1. December 2014 - MPI issued urgent measures to require vehicles and machinery from the United States of America to be fumigated or heat treated prior to shipment to New Zealand or mandatory treatment on-arrival (containerised risk goods). Treatments where based on the best information available at the time and what was available at the point of export. These measures were:
    - Methyl bromide fumigation at 48 g/m^3 at 10-15°C for 24 hours; or
    - Methyl bromide fumigation at 40 g/m^3 at 15-21°C for 24 hours); or
    - Heat treatment at 60°C for 10 minutes for vehicles weighing less than 3,000 kg; or
    - Heat treatment at 60°C for 20 minutes for vehicles weighing more than 3,000 kg.

2. February 2015, a CTO direction (2015 0038) was issued that allowed the use of Sulfuryl fluoride fumigation as an additional efficacious pre-export treatment. The rates imposed were:
    - Sulfuryl fluoride fumigation at 32 g/m^3 at 21-25°C for 24 hours; or
    - Sulfuryl fluoride fumigation at 40 g/m^3 at 16-20°C for 24 hours.

3. September 2015 - a MPI technical review for Brown Marmorated Stink Bug treatments was released which recommended:

- Sulfuryl fluoride schedule: An applied dose of 16 g/m^3 at 10°C for 12 hours or greater with a 50% minimum final reading;
- Methyl bromide schedule: An applied dose of 16 g/m^3 at 10°C + for 12 hours with a minimum final reading of at least 50%.
- Heat schedules: 50^{o}C for 20 minutes for vehicles and machinery <3,000kg and 50^{o}C for 30 minutes vehicles and machinery >3,000kg.

4. October 2015 - a CTO direction (2015 0040) allowing Sulfuryl fluoride fumigation at 16 g/m^3 for 12 hours at 10°C or greater with a 50% end point reading.

5. August 2017 - MPI issued urgent measures to treat vehicles and machinery from Italy.

6. December 2017 - MPI issued urgent measures to require sea containers with any contents of Italian origin or shipped via Italy to be treated prior to shipment to New Zealand or mandatory treatment on-arrival. This was extended until 30th of April 2018.

7. January 2018 - issued a CTO direction for other measures such as reduced Methyl bromide or enhanced inspection for sensitive cargo.

8. February 2018 - MPI issued urgent measures for all used vehicles and machinery imported from Japan to be processed through an MPI-approved system prior to shipment due to increased Brown Marmorated Stink Bug finds. All vessels carrying vehicles from Japan were insecticide fogged and had increased verification actions conducted. A revised (draft) Import Health Standard has been consulted on requiring new vehicles from a wide range of countries to be processed through an MPI-approved system or be treated; and all used vehicles to be treated during the Brown Marmorated Stink Bug season (between the 1st of September through to the 30th of April).

9. February 2018 - Another MPI technical review was released with the scientific information underpinning the proposed Brown Marmorated Stink Bug treatment changes. This occurred as the treatment schedules that were formally consulted on in September 2015 were challenged by some stakeholders and subsequently reviewed by Dr. M. Ormsby. The conclusions were:

    a. a reduced Methyl bromide fumigation rate of >140 g.h/m^3 at >10°C and >120 g.h/m^3 at >15°C, applied over a 12-24 hour period, should ensure (at the 95% level of confidence) no more than one non-diapausing BMSB adult survives in 1,000 exposed individuals.
    b. A reduced Sulfuryl fluoride fumigation rate of >135 g.h/m^3 for treatments at >10°C, applied over a >12 hour period at a minimum concentration of 8 g/m^3, should ensure (at the 95% level of confidence) no more than one (non-diapausing) BMSB adult survives in 290 exposed individuals.
    c. A heat treatment of 56°C for 30 minutes or 60°C for 1 minute, at the coldest location BMSB could be found on any treated vehicle, should ensure (at the 95% level of confidence) no more than one BMSB adult survives in 1,000 exposed individuals.
    d. Diapausing adults are more tolerant of fumigation than non-diapausing adults.

3 DISCUSSION

3.1 BROWN MARMORATED STINK BUG TREATMENT RATES

While the treatment rates for Brown Marmorated Stink Bug have been working well over three seasons for cargo from the United States of America and one season of Italian cargo destined for both Australia and New Zealand on approximately 60,000 vehicles (plus containers), there has been much discussion over the required efficacy for mortality. After assessing the infestation rate of Brown Marmorated Stink Bug and cargo volumes across the

various pathways, it has been agreed within MPI and with our stakeholders that with a suitable level of confidence (95%) that a 99.9% level of treatment efficacy (no survivors in 1,000) is an acceptable level of efficacy to control Brown Marmorated Stink Bug.

There have been three "failures" of an offshore treatment where live aggregations where found on arrival that have been assessed as poor fumigation technique or fraudulent certificates from one particular company that is no longer recognised by MPI or the Australian Department of Agriculture and Water Resources (Australian Department). MPI but will be concentrating in the short term of improving the application of treatments offshore (particularly in Italy) in conjunction with the Australian Department. A joint investigation visit by representatives from both countries to meet treatment providers has been carried out and more are planned.

All the treatments have some issues for treating different the different commodities – Methyl bromide is an ozone depleting chemical and not generally available in the United States for treating vehicles and machinery; and not available in Europe. There are also concerns over the effects on some components such as rubber. Sulfuryl fluoride has a high Global Warming Potential (5,000 times greater than CO_2) but is less reactive to components and available in the United States and Europe and preferred by vehicle manufacturers. Heat has wide application but needs to be carefully applied and some motorhomes have been damaged in the past.

Fumigant exposures, expressed as concentration (*C*) × time (*t*) products (*Ct*), are calculated following IPPC 2014-004 Draft ISPM Requirements for the use of fumigation as a phytosanitary measure.

Efficacy levels also differ for different pests and life stages, for instance Sulfuryl fluoride needs a higher dose rate to control some other pests on such as *Latrotectus* spp. (Redback and Black/Brown Widow spiders) or Asian Gypsy Moth eggs when compared to Methyl bromide.

3.1.1 Sulfuryl fluoride fumigation

Sulfuryl fluoride is the preferred fumigant for vehicle manufacturers in the United States of America as Methyl bromide is not widely available. In Europe, Methyl bromide has been phased out, and some manufacturers have concerns over the effect of the fumigant on vehicle components. One of the main export ports in the United States of America (Baltimore, Maryland) has a resource consent restriction on venting Sulfuryl fluoride so the treatment facility and associated dosage rate needs to meet local regulations. The current dose rate (16 g/m^3) enables compliance with the current active venting process.

Walse et al (2015) recommended a Sulfuryl fluoride concentration time product (*Ct)* of 142.8 mgL^{-1}h This was purported to be the Probit 9 rate calculated for the most resistant summer life stage (2nd instar nymphs) of Brown Marmorated Stink Bug. This equates to a constant rate of 12 g/m^3 over 12 hours under sealed laboratory conditions. When this information is coupled with the normal expectation of commercial fumigation processes and a minimum final concentration reading of 50% of the starting concentration, the initial dose needed to be adjusted to allow for any gas loss or sorption by the treated cargo. Using a straight line decline in concentration gives a starting dose of 16 g/m^3 and an end point reading of 8 g/m^3 to achieve the same *Ct* as under the reported laboratory conditions.

As a commercial example, good gas retention at the large Baltimore fumigation facility is achieving a concentration time factor of 254 g.h. This is because the fumigation is usually left to run longer than required as the process is normally carried out overnight. For the first 12 hours, a *Ct* of 180 g.h/m^3 is being achieved. Similar readings were being obtained at the other major United States of America vehicle export port in Savannah, Georgia. The blue line in *Figure 1* is the calculated readings used to arrive at the current fumigation schedule and as can be seen, these requirements are being exceeded.

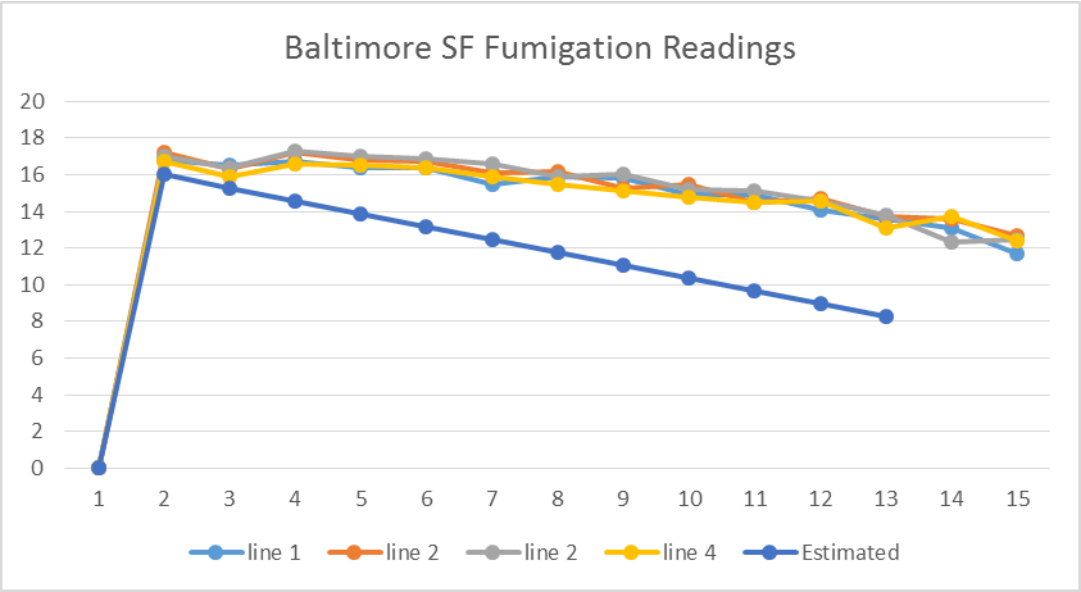

Figure 1: Fumigation readings recorded at a Baltimore car fumigation facility

MPI conducted a review of available information on Brown Marmorated Stink Bug treatments (Ormsby 2018). Taking the exposed numbers without extrapolation, the research data indicated that a treatment dose (*Ct* value) of 144 g.h/m^3 over 12 hours provides 97.1% efficacy at the 95% level of confidence (no survivors in 34). Combining the trade volume (2015-16 season) treated with the number treated by Walse (2015) at a similar rate (103 non-diapausing adults) gives a total exposed adult population with no survivors of 869, or an efficacy level of 99.65% (no survivors in 290) at the 95% level of confidence using a reduced Sulfuryl fluoride fumigation rate achieving a *Ct* of >135 g.h/m^3 over a 12 hour period.

MPI commissioned specific research to undertake "range finder" trials on Brown Marmorated Stink Bug and to test the suitability of using the green vegetable bug *Nezara viridula* as a surrogate so further testing of high numbers for efficacy could be carried out easily. The final report (draft) for the operational research on Brown Marmorated Stink Bug adult specimens collected in summer when fumigated with Sulfuryl fluoride shows that it almost half the dose (8 to 10 g/m^3), and nearly the same *Ct* (96 to 120 g.h) as that set by the current schedules for Sulfuryl fluoride (at 16 g/m^3 for 12 hours at 10°C or greater with a 50% end-point reading and which aims to achieve a *Ct* of 140 g.h) is effective for mortality.

The only comparison for overwintering Brown Marmorated Stink Bug versus summer specimens noted in another small set of data (Abrams pers. comm. 2018). It appears that Sulfuryl fluoride is a slower acting fumigant than Methyl bromide so a longer duration is better than a shorter duration and this is also the experience on fumigating stored product for pests which is currently the main use for Sulfuryl fluoride.

In the Abrams draft report, it shows that for a 12 hour duration at 10°C a Ct of between 66 and 90 g.h is required for summer stages whereas 135 to 180 g.h is needed for mortality of winter stages. Data gathered illustrates that when the time is extended from 8 to 12 hours, 31% less fumigant is required. Only two replicates of winter bugs were tested but the data obtained clearly indicates that winter aggregating Brown Marmorated Stink Bug may need twice the fumigant level to kill them compared to the summer adult specimens. At this stage, there is insufficient data to demonstrate at a 95% level of confidence that this dose is effective to kill 99.9% of adult diapausing BMSB. The data indicates that more fumigant may be required for the required mortality and MPI is planning on undertaking more trials to confirm the treatment schedule efficacy.

From July 2015, the Australian Department approved the use of a Sulfuryl fluoride fumigation rate (16 g/m^3 for 12 hours with 50% retention) for Brown Marmorated Stink Bug (Australian Department of Agriculture and Water Resources 2015) and in September 2015, MPI also approved the same schedule. As the both the Australian and New Zealand break-bulk cargo is treated within the same treatment facilities, having an aligned treatment schedule means there is an improved level of compliance. They also had a six hour rate which has been discontinued due to the uncertainty around what increase in C*t* is required when reducing the time.

Both the Australian Department and MPI consider that the 16g/^{3} Sulfuryl fluoride rate utilised since 2015 has been successful for killing Brown Marmorated Stink Bug over three seasons for cargo (estimated to be approximately 60,000 vehicles) from the United States of America and one season of cargo from Italy.

There have been three "failures" of "treated" cargo from Italy where aggregations of live Brown Marmorated Stink Bug were found after having been certified as treated with Sulfuryl fluoride at 64 g/m^3 and 21^{o}C for 16 hours by the same treatment supplier. This is theoretically four times the rate required for mortality of Brown Marmorated Stink Bug. It is considered that either no fumigant was applied or the cargo was re-infested (which is considered to be unlikely for two shipments as they were both containerised). A visit was made to the particular treatment company which confirmed the suspicion that the fumigation was not carried out correctly and it was formally notified that MPI and Australian Department are no longer accepting their certificates.

MPI will concentrate in the short term of improving the application of treatments offshore in conjunction with Australian Department, particularly in Italy. A joint country visit occurred in March 2018 and the Australian Department is conducting another in July. Treatment suppliers in Italy will be formally approved by the 1st of September 2018. For ongoing treatment using Sulfuryl fluoride, there are two options considered

Option 1 – retain the current CTO approved rate of Sulfuryl fluoride at:

- 16 g/m^3 at 10°C for 12 hours or greater with an 8 g/m^3 minimum final reading, to achieve a C*t* of 140 g.h/m^3.

or

Option 2 – Sulfuryl fluoride increased to:

- a rate of at least a C*t* of 200 g.h/m^3 over a minimum of 12 hours at 10°C or above – this can be achieved by applying 20 g/m^3 for a minimum of 12 hours with an end point reading of 14 g/m^3 (70%) or more of the initial concentration.

Due to some evidence that the aggregating stink bugs are more resistant to fumigants than first thought, MPI intends to slightly increase the Sulfuryl fluoride fumigation schedule by 43% and will continue to investigate and undertake more research. It does need to be noted that the recommended schedule will not control some other pests on this pathway such as *Latrotectus spp*. (Redback and Black/Brown Widow spiders) or Asian Gypsy Moth eggs.

MPI recommended Sulfuryl fluoride schedule: This is an applied rate to achieve at least a C*t* of 200 g.h/m^3 over a minimum of 12 hours at 10°C or above. This can be achieved by applying 20g/m^3 for a minimum of 12 hours with an end point reading of 14 g/m^3 (70%) or more of the initial concentration

3.1.2 Methyl bromide fumigation

The MPI schedule for dealing with a wide range of pests found on vehicles and the default schedule for Brown Marmorated Stink Bug has used the following specifications:

- Methyl bromide fumigation at 48 g/m^3 for 24 hours at 10-15°C; or
- Methyl bromide fumigation at 40 g/m^3 for 24 hours at 15-21°C; or

This is likely to achieve a C*t* product of around 650 g.hrs/m^3 at 10-15^{o}C. At the early stage of dealing with finding treatments for the stink bug a prominent treatment research scientist from United States Department of Agriculture Research Service (Walse pers. comm.) supplied MPI with results of research on the control of BMSB with two hour Methyl bromide fumigations. At 15.6° C and normal atmospheric pressure, Probit analysis of the most Methyl bromide-tolerant summer life stages (2nd & 3rd instar) suggested the following C*t* exposures:

LE99=40.494 mg L-1 h with 95% confidence limits: 31.571 to 59.887

LEP9=90.033 mg L-1 h with 95% confidence limits: 60.675 to 179.997

For the September 2015 review of treatments, the average LE P9 C*t* was been used and some 50 mg L-1 h was added to the Methyl bromide schedule to achieve a 140 C*t* to allow for the practical aspects of commercial application and sorption/reactivity with Methyl bromide on some items. Normal experience with fumigants is that a longer exposure requires a reduced dose and allows the fumigant to penetrate better into the commodity. The fumigation time was extended to 12 hours to allow this to occur. This was calculated with the same method used as for Sulfuryl fluoride to 16 g/m^3 for 12 hours at 15°C+ with an end point reading of 50%.

Since a reduced rate of Methyl bromide was first proposed in September 2015 it was reviewed by Ormsby (2018) who concluded that treatment rates of Methyl bromide *Ct* >140 g.h/m^3 at >10°C would achieve sufficient levels of efficacy against non diapausing adults of the Brown Marmorated Stink Bug. It should be noted that this rate is significantly greater than that applied for the majority of other fruit pests.

MPI commissioned research to undertake "range finder" trials on Brown Marmorated Stink Bug with Methyl bromide and to test the suitability of using the Green Vegetable Bug (*Nezara viridula)* as a surrogate test insect so further testing could be carried out easily. The draft report shows that a C*t* of 54 to 72g.h over 6 hours at 10^{o}C achieved 100% mortality of the summer form of Brown Marmorated Stink Bug which is half that of the proposed Methyl bromide fumigation mentioned above of *Ct* of 140 g.h/m^3. This follows the trend between summer and winter forms of the bug when treated with Sulfuryl fluoride. Due to the lack of specimens there was only one test of the rate required for winter specimens that achieved 97% mortality at a C*t* result of 120g.h over 6 hours at 10^{o}C. A Probit 9 calculation based on the limited data curve arrived at an upper limit *Ct of 172g.h.* While this was based on small numbers of Brown Marmorated Stink Bug, it is a useful indicator, and MPI is planning on undertaking more trials to confirm the treatment schedule.

The rates approved by the Australian Department for Brown Marmorated Stink Bug are:

- a rate of at least 16 g/m³ at 15°C for a minimum of 12 hours with an end point reading of 50% or more of the initial concentration, or

- a rate of at least 32 g/m³ at 21°C for a minimum of 24 hours with a 30% retention.

Normally Methyl bromide schedules (FAO 79, FAO 54, USDA APHIS, MPI ABTRT 2018) allow an increase of 8 g/m^3 for every 5^{o}C drop in temperature which would equate to 24 g/m^3 at 10-15^{o}C.

Based on the data available the Methyl bromide fumigation options are:

Option 1 – retain the current Methyl bromide schedule of:

- Methyl bromide fumigation at 48 g/m^3 for 24 hours at 10-15°C; or
- Methyl bromide fumigation at 40 g/m^3 for 24 hours at 15-21°C;

or

Option 2 – use the following Methyl bromide specifications:

- 16 g/m^3 at 10^{o}C+ for 12 hours with a minimum final reading of at least 50% (8 g/m^3) achieving a C*t* of 140 g.h/m^3.

or

Option 3 – use the following Methyl bromide specifications:

- a rate of at least a C*t* of 200 g.h/m^3 over a minimum of 12 hours at 10°C or above – this can be achieved by applying 24 g/m³ for a minimum of 12 hours with an end point reading of 50% (12 g/m^3) or more of the initial concentration.

There is a need to optimise Methyl bromide schedules to meet the aims of the Montreal Protocol and IPPC Reduce and Replace Recommendations due to it being an ozone depleting gas, and reduce adverse effects on commodities such as tainting. A range of commodities, fumigation circumstances (under cover, chambers and containers) and the behaviour of the gas (sorption into commodities) must also be allowed for. Hence the schedule has been reduced but the higher C*t* rate has been chosen to allow for variables above what is known and the best estimate as to what the Probit 8 level could be to meet the required efficacy level.

MPI recommended Methyl bromide schedule: An applied dose of a rate of at least a C*t* of 200 g.h/m^3 over a minimum of 12 hours at 10°C or above – this can be achieved by applying 24g/m³ for a minimum of 12 hours with an end point reading of 50% (12 g/m^3) or more of the initial concentration.

It does need to be noted that this schedule will not control some other pests on this pathway such as *Latrotectus spp*. (Widow Spiders).

3.1.3 Heat treatment

As noted in the Treatment Technical Review (MPI 2015), Aigner & Kuhar (2016) exposed small numbers of adult Brown Marmorated Stink Bug (~40) to increasing temperatures and exposure times. They found that none survived temperatures of 45°C for more than an hour or and none survived 50°C for more than 15 minutes. The Australian Department adopted 50^{o}C for 20 mins as a treatment schedule in 2015. As reviewed by Ormsby, these results indicate that Brown Marmorated Stink Bug (like many other insect pests) is likely to undergo high levels of mortality (e.g. no survivors in >10,000 adults) under the ISPM 15 (FAO 2009) wood packaging heat treatment schedules of 56°C for 30 minutes or 60°C for 1 minute. It has been noted that some Brown Marmorated Stink Bug heat treatments are being undertaken by ISPM 15 approved providers so matching the ISPM schedule is an advantage.

While Brown Marmorated Stink Bug may possibly be managed by different temperature and time combinations e.g. lower temperatures and/or shorter treatment times more proof is needed. Also there is still some doubt on being able to approve a different temperature or time with the variety of sizes and weights of vehicles and machinery that require treatment. If evidence is provided to MPI that the required efficacy for a different temperature or time and heat treatment operators can raise every internal and external part of the wide variety and number of the vehicles that are required to that heat schedule e.g. be treated to 60^{o}C consistently for 1 minute, then it may be considered an equivalent treatment.

Recommended heat schedules: 56^{o}C for 30 minutes (all sizes of vehicles and machinery),

60^{o}C for 10 minutes for vehicles and machinery <3,000kg; and

60^{o}C for 20 minutes vehicles and machinery >3,000kg.

3.1.4 Aircraft, Boats, Helicopters

Multiple CTO directions for aircraft, boats and helicopters have been issued with a different applied measure (inspection and insecticide) to manage the risk posed by Brown Marmorated Stink Bug. These measures have been considered to be equivalent to the Import Health Standard requirements mentioned above for this type of good. The importers have repeatedly claimed that fumigation or heat treatment could adversely affect aircraft, boats and helicopters and that using equivalent measures poses a lower risk of damage to them.

The visual inspection, cleaning and residual pesticide treatment applied to such craft is likely to have detected, removed and killed any BMBS that might be incidentally associated these risk goods. No live stink bugs have been found on arrival in New Zealand. Therefore, that when the type of good, source of the craft, the application of a residual insecticide and inspection it is considered to be a sufficient level of control as required otherwise in the Import Health Standard. The insecticides are known to control adult Brown Marmorated Stink Bugs (Kuhar 2017, Leskey 2012) and it has been noted that synthetic pyrethroids have an irritating effect on Brown Marmorated Stink Bug causing them to move out of hiding even when they are in the aggregation phase. It should also be noted that the same process was approved by Australian Department for boats.

Recommended treatment: Use of Bifenthrin, Cyphenothrin, Permethrin or Silafluofen (residual synthetic pyrethroid insecticides) at the maximum label rates.

4 Conclusion

The following measures are deemed suitable for treatment of the Brown Marmorated Stink Bug:

1. **Heat treatment:**
   56°C for 30 minutes (all sizes) or
   60°C for 10 minutes for <3,000kg and
   60°C for 20 minutes >3,000kg
2. **Methyl bromide fumigation:** An applied dose of a rate of at least a C*t* of 200 g.h/m^3 over a minimum of 12 hours at 10°C or above. This can be achieved by applying 24g/m^3 for a minimum of 12 hours with an end point reading of 50% (12 g/m^3) or more of the initial concentration.

   Note that this Methyl bromide fumigation schedule will not control some other pests on this pathway such as *Latrotectus spp*. (Redback and Black/Brown Widow spiders).

3. **Sulfuryl fluoride fumigation:** An applied dose of a rate of at least a C*t* of 200 g.h/m^3 over a minimum of 12 hours at 10°C or above. This can be achieved by applying 20g/m^3 for a minimum of 12 hours with an end point reading 14 g/m^3 (70%) or more of the initial concentration.

   Note that this Sulfuryl fluoride fumigation schedule will not control some other pests on this pathway such as *Latrotectus spp*. (Redback and Black/Brown Widow spiders) or Asian Gypsy Moth eggs.
4. Treatment of aircraft, boats and helicopters: Bifenthrin, Cyphenothrin, Permethrin or Silafluofen (residual insecticides) at the maximum label rates.

The treatments will be listed in the MPI: *Approved Biosecurity Treatments* Technical Standard.

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